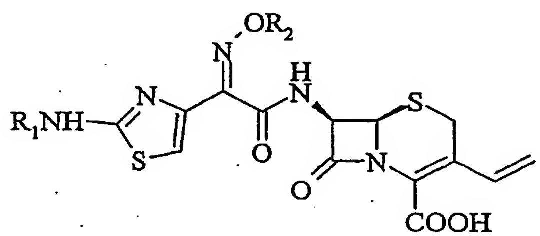
INTERMEDIATE CEFDINIR SALTS

Field of the invention

The present invention relates to cephalosporins, in particular to cefdinir intermediates and to a process for the preparation of said intermediates.

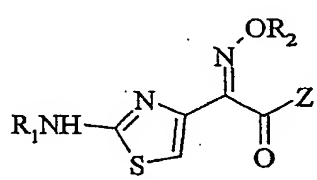
Summary

The present invention relates to salts of general formula (I)

(I)  x B

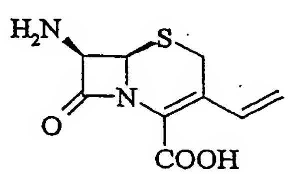
wherein R_1, R_2 and B are as defined in the description. These salts are useful as intermediates for the preparation of cefdinir.

Compounds (I) can be obtained through a process comprising the reaction of a compound of formula (II)

(II) 

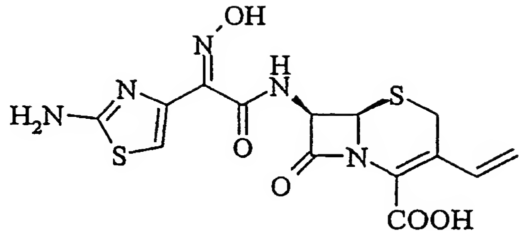
wherein R_1 and R_2 are as defined in the description,

with 7-amino-3-vinyl-3-cephem-4-carboxylic acid of formula (III)

(III) 

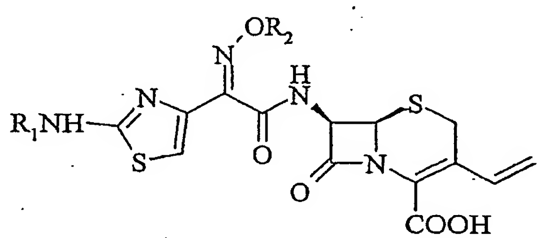
Background of the invention

[(-)-(6R,7R)]-7-((Z)-2-(2-Amino-4-thiazol)-2-hydroxyiminoacetamido)-8-oxo-3-vinyl-5-thia-1-azabicyclo[4.2.0]-oct-2-ene-2-carboxylic acid (IV), commonly known as cefdinir,

(IV) 

is a third generation semisynthetic cephalosporin for oral use, characterized by a broad antibacterial spectrum against gram-positive and gram-negative bacteria, its antibiotic activity being higher than that of other antibiotics for oral administration. In particular, it shows excellent antibacterial activity against staphylococci and streptococci.

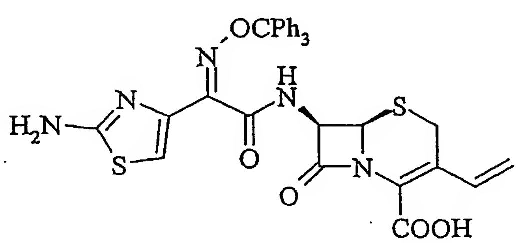
Cefdinir is usually synthesized through intermediates of formula (V) wherein the hydroxyimino group (and optionally the primary amino group) is protected

(V) 

R_1 and R_2 being as defined in the description.

According to the literature, the intermediates (V) can be obtained in different ways, but their recovery is troublesome and not convenient from the industrial standpoint.

For example, according to WO 97/24358, an intermediate of formula (V) wherein R_1 is hydrogen and R_2 is trityl (Va), is recovered as the salt with p-toluenesulfonic acid (VIa)

(VIa)  x p-TsOH x 2 Me_2NCOMe

The drawback of this method is that the recovery is accomplished by adding to the reaction mixture anti-solvents such as ethers, which are dangerous and therefore not suitable for industrial use.

Other methods do not envisage recovery of the intermediates (V); as a consequence, the quality of the final product is poor and further purifications are required (WO 98/45299; Kamachi, H. et al., *J. Antibiot.* 1988 *41(11)*, 1602-16).

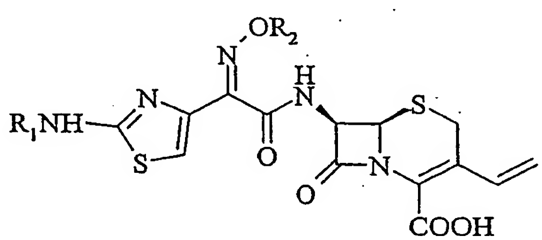
Alternatively, the side chain can be linked to the cephalosporanic nucleus by means of subsequent synthetic steps, with decrease in the overall yield and increase in the process time (US 4559334, EP 304019).

The intermediates (V) can also be recovered from water as free acids, but filtration and drying are very difficult.

DETAILED DESCRIPTION OF THE INVENTION

It has now been found that the intermediates (V) can be recovered in high yield and purity as the salts with ammonia or organic bases, in inert organic solvents of common industrial use, thus remarkably improving the manufacture of cefdinir in terms of time, costs and quality of the end product.

Accordingly, the present invention relates to salts of formula (I)

(I)  x B

wherein

R_1 is hydrogen or an amino-protecting group, for example a C_1-C_6 acyl group optionally substituted with one or more fluorine or chlorine atoms, preferably formyl, an alkyl- or aryl-oxycarbonyl group, preferably tert-butoxycarbonyl and p-methoxybenzyloxycarbonyl, or a trityl group wherein each benzene ring is optionally substituted with one or more methoxy

and/or methyl groups, preferably trityl;

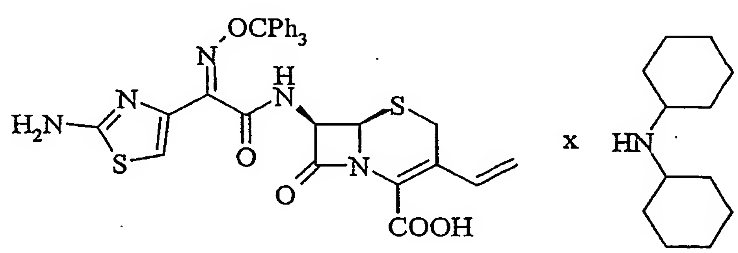
R_2 is a hydroxy-protecting group, for example a straight or branched C_1-C_6 alkyl group, preferably tert-butyl, a benzyl, benzhydryl or trityl group wherein each benzene ring is optionally substituted with one or more methoxy, nitro and/or methyl group, preferably p-methoxybenzyl, 3,4-dimethoxybenzyl, benzhydryl, bis(p-methoxyphenyl)methyl and trityl;

B is ammonia or an organic base selected from primary amines, preferably cyclohexylamine, 2-ethylhexylamine, benzylamine, α-methylbenzylamine and tert-octylamine; secondary amines, preferably diethylamine, morpholine, dicyclohexylamine, N,N-methylbenzylamine or N,N'-dibenzylethylenediamine; tertiary amines, preferably triethylamine, tributylamine, triisooctylamine, ethyldiisopropylamine, N-methylmorpholine, pyridine, 2,6-lutidine or quinoline; guanidine, preferably 1,1,3,3-tetramethylguanidine; amidines, preferably 1,5-diazabicyclo[4.3.0]non-5-ene (DBN) or 1,8-diazabicyclo[5.4.0]undec-7-ene (DBU);

hydrates, solvates or adducts thereof.

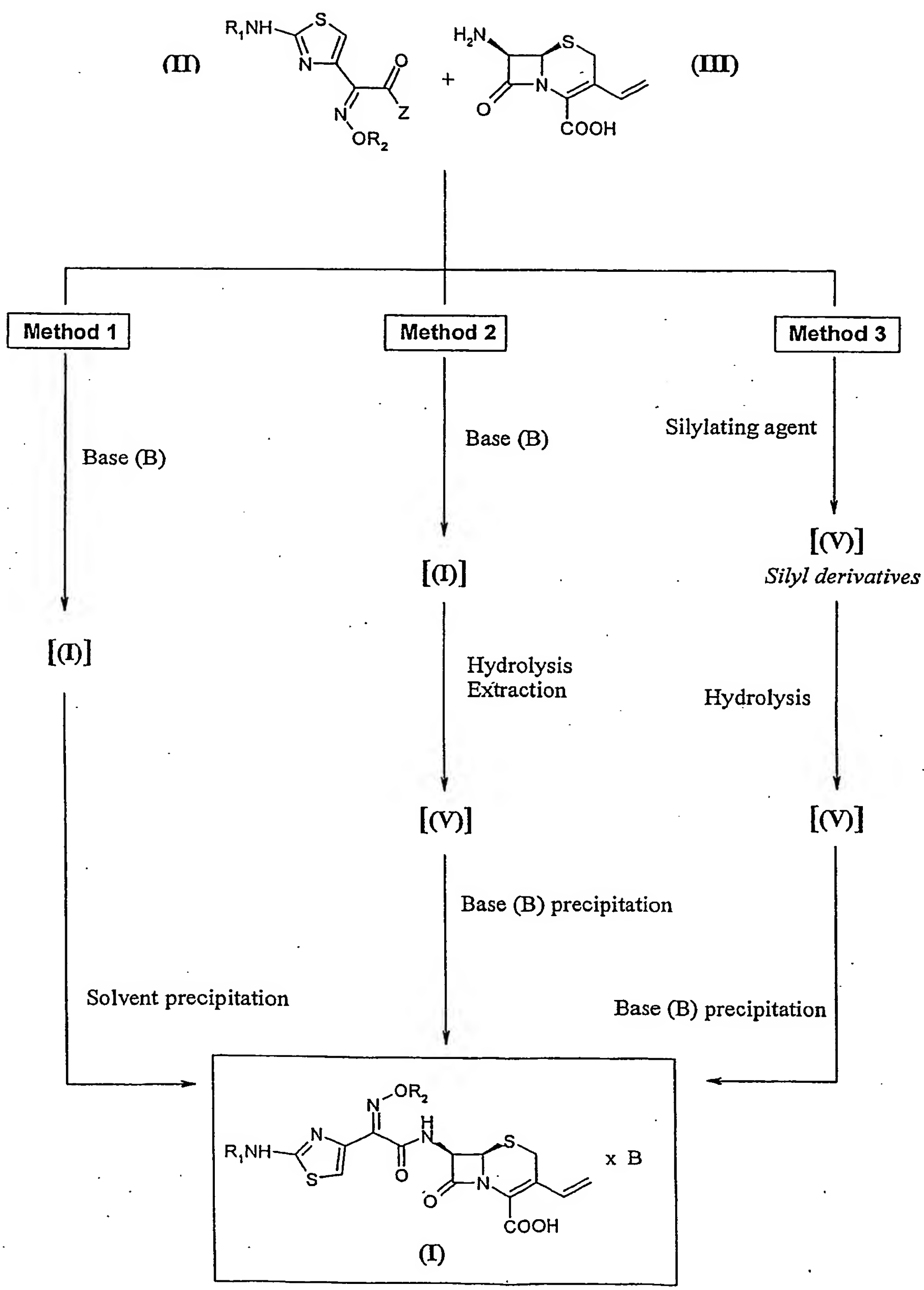
A preferred salt according to the invention is the dicyclohexylamine salt of the formula (Ia)

(Ia)

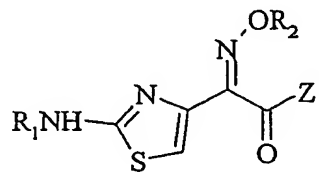


The salts of formula (I) are obtained through a process which envisages three possible alternatives, whose common feature is that the acids of the formula (V) are not isolated. The alternatives are illustrated in the following scheme.

Scheme

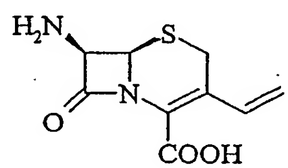

(II)
(III)
Method 1
Method 2
Method 3
Base (B)
Base (B)
Silylating agent
[(V)]
Silyl derivatives
[(I)]
[(I)]
Hydrolysis
Extraction
Hydrolysis
[(V)]
[(V)]
Base (B) precipitation
Solvent precipitation
Base (B) precipitation
x B
(I)

In a first embodiment of the invention (method 1), an activated 2-(aminothiazol-4-yl)-2-(hydroxyimino)acetic acid derivative of formula (II)

(II) 

wherein R_1 and R_2 are as defined above and Z is a carboxy-activating group selected from -Cl, -S-mercaptobenzothiazolyl, -O-$P^+(Ph)_3Cl^-$, -O-$P(S)(OEt)_2$, -O-$P(O)(OEt)_2$, -O-SO_2Me, -O-SO_2Ph, -O-SO_2-pTol, -O-COtBu, -O-C(O)OEt, -O-benzotriazol-1-yl, -S-(2-methyl-thiadiazol-5-yl), -O-$CH=N^+(CH_3)_2Cl^-$ or benzotriazol-1-yl-3-oxide,

is reacted with 7-amino-3-vinyl-3-cephem-4-carboxylic acid (III),

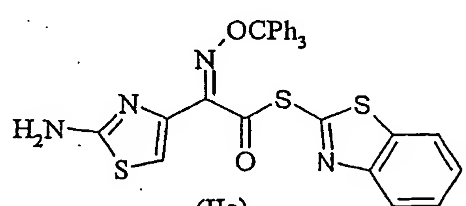
(III) 

in the presence of ammonia or an organic base selected from those listed above. The compounds (II) and (III) comprise also their hydrates and solvates. The reaction is carried out in an organic solvent selected from: halogenated hydrocarbons, preferably methylene chloride; carboxylic acid esters, preferably dimethylcarbonate, ethyl acetate and butyl acetate; ketones, preferably acetone, methyl ethyl ketone and methyl isobutyl ketone; nitriles, preferably acetonitrile or propionitrile; amides, preferably N,N-dimethylformamide, N,N-dimethylacetamide, N-methylpyrrolidone; aromatic hydrocarbons, preferably toluene and xylene; ethers, preferably tetrahydrofuran, dioxane or ethylene glycol dimethyl ether; sulfoxides or sulfones, preferably dimethylsulfoxide, dimethyl sulfone and sulfolane; alcohols, preferably methanol or ethanol, or mixtures thereof, optionally in the presence of water, at a temperature ranging from -20°C to +80°C, preferably

from 0°C to 40°C. Preferred solvents according to the invention are N,N-dimethylformamide and N,N-dimethylacetamide. The amount of base can be stoichiometric to the compound of formula (III) or in molar excess up to 3 times, preferably ranging from 1 to 2 equivalents.

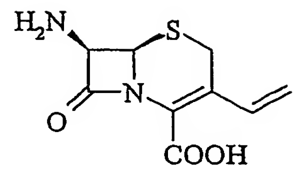
The resulting salts of the formula (I) precipitate by addition of an anti-solvent selected from those listed above. The crystallization temperature may range from -20°C to 50°C, preferably from -10°C to 30°C.

In a second embodiment of the invention (method 2) the reaction is carried out as described above, but the salts (I) are not immediately precipitated, rather converted to an acid of the formula (V), which is extracted from the reaction mixture and precipitated from the extraction solvent by treatment with ammonia or an amine selected from those listed above, which can be the same or different from that used in the previous step. The salt is precipitated using an amount of base stoichiometric to the acid of the formula (V) or in molar excess up to two times, preferably ranging from 1 to 1,5 equivalents. Also in this case the crystallization temperature may range from -20°C to 50°C, preferably from -10°C to 30°C. According to a preferred embodiment of this method, compounds (II) and (III) are reacted with 1,1,3,3-tetramethylguanidine or triethylamine. Preferably, the compound of formula (II) is the S-mercaptobenzothiazolyl thioester (IIa)

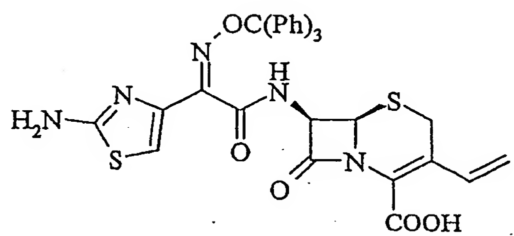


(IIa)

and the compound of formula (III) is 7-amino-3-vinyl-3-cephem-4-carboxylic acid (III)

(III) 

In a third embodiment of the invention (method 3), the reaction between the compounds (II) and (III) is carried out in the presence of a silylating agent, preferably N,O-bis-trimethylsilylacetamide. The acid of formula (V) obtained after hydrolysis is extracted and precipitated as a salt of formula (I) by treatment with ammonia or with an amine selected from those listed above. Also in this case, use will be made of an amount of base stoichiometric to the acid of formula (V) or in molar excess up to two times, preferably ranging from 1 to 1,5 equivalents. According to a preferred embodiment of this method, the ester (IIa) is reacted with the acid (IIIa) in the presence of N,O-bis-trimethylsilylacetamide, to give, after hydrolysis, the acid (Va)



(Va)

Among the three methods disclosed above, the second and the third ones are particularly preferred, as they allow to obtain the salts of formula (I) with higher purity.

The salts (I) precipitate as crystals from the reaction mixture and can be easily recovered by filtration or centrifugation. Through crystallization of the salts (I), the intermediates (V) are removed off the reaction medium; degradation is thus remarkably reduced, while the yield and quality of the intermediates are increased. The salts (I) can be obtained in the anhydrous form, or as hydrates, or can also be recovered as solvates. Hydration water or

solvation solvent can be sometimes removed in part or almost completely by drying under reduced pressure, which increases the stability of the product. Typically, a salt having a water content of 0.5% or lower and a solvent content of 3% or lower can be obtained after drying. The salts of formula (I) can also be recovered as adducts with derivatives of formula H-Z, wherein Z is as defined above. The derivatives of formula H-Z can be present in a molar ratio of 1:1 or lower.

The conversion of the salts (I) to cefdinir (IV) by removal of the protecting groups can be carried out according to methods already known in the literature (WO 0179211, WO 9724358, Kamachi, H. et al., *J. Antibiot.* **1988** *41(11)*, 1602-16).

The following examples illustrate the invention in greater detail.

EXAMPLES

<u>Example 1</u>

Preparation of 7-[2-(aminothiazol-4-yl)-2-(trityloxyimino)-acetamido]-3-vinyl-3-cephem-4-carboxylic acid dicyclohexylamine salt

1,1,3,3-Tetramethylguanidine (35.8 ml) is added in 15 min to a suspension of 7-amino-3-vinyl-3-cephem-4-carboxylic acid (65.0 g) in N,N-dimethylformamide (0.78 L) previously cooled to 10°C and the mixture is stirred at this temperature until complete dissolution. 2-(Aminothiazol-4-yl)-2-(trityloxyimino)acetic acid S-mercaptobenzothiazolic ester (172.7 g) is added thereto in 15 min and the mixture is stirred at this temperature until complete conversion of 7-amino-3-vinyl-3-cephem-4-carboxylic acid (HPLC analysis). After completion of the reaction, water (1.7 L) and ethyl acetate (2.2 L) are added and the pH is adjusted to 3.0 with diluted hydrochloric acid. The phases are separated and the organic one is washed with a 20% sodium chloride solution in water (0.86 L). The phases are separated and dicyclohexylamine (54.1 ml) is added in 30 min to the organic one. Formation

of crystals is observed. After further 15 min the mixture is cooled to 0°C, stirred at this temperature for 1 hour, thereafter the precipitate is filtered, washed with ethyl acetate (1.7 L) and dried. 226.0 g of the title compound are obtained.

^{1}H-NMR (DMSO-d_6, 300 MHz): 9.86 (1H, d, *J*=8.3 Hz, -CON*H*-), 7.34-7.20 (15H, m, *Ph₃*), 7.01 (1H, dd, *J*=17.9 e 11.6 Hz, -C*H*=CH_2), 6.59 (1H, s, *H*-heteroaryl), 5.78 (1H, dd, *J*=8.3 and 5.0 Hz, -CONH-C*H*-), 5.24 (1H, d, *J*=17.9 Hz, -CH=CH*H* trans), 5.15 (1H, d, *J*=5.0Hz, -CON-CH-), 5.00 (1H, d, J=11.6 Hz, -CH=CH*H* cis), 3.61 (1H, AB system, J_{AB}=17.0 Hz, -SCH_2), 3,46 (1H, AB system, J_{AB}=17.0 Hz, -SCH_2), 3.06-3.00 (2H, m, 2 x HN-C*H* dicyclohexylamine), 1.99-1.06 (20H, m, 10 x CH_2 dicyclohexylamine).

Example 2

Preparation of 7-[2-(aminothiazol-4-yl)-2-(trityloxyimino)-acetamido]-3-vinyl-3-cephem-4-carboxylic acid dicyclohexylamine salt

Triethylamine (9.1 ml) is added in 20 min to a suspension of 7-amino-3-vinyl-3-cephem-4-carboxylic acid (7.5 g) in N,N-dimethylformamide (90 ml) previously cooled to 15°C. 2-(Aminothiazol-4-yl)-2-(trityloxyimino)acetic acid S-mercaptobenzothiazolic ester (19.7 g) is added thereto in 15 min and the mixture is stirred at this temperature until complete conversion of 7-amino-3-vinyl-3-cephem-4-carboxylic acid (HPLC analysis). After completion of the reaction water (200 ml) and ethyl acetate (250 ml) are added and the pH is adjusted to 3.0 with diluted hydrochloric acid. The phases are separated and the organic one is washed with a 20% sodium chloride solution in water (200 ml). The phases are separated and dicyclohexylamine (7.2 ml) is added to the organic one in 15 min. Formation of crystals is observed. After further 15 min the mixture is cooled to 0°C, stirred at this temperature for 1 hour, thereafter the precipitate is filtered, washed with ethyl acetate (100 ml) and dried. 26.4 g of the title compound are obtained.

Example 3

Preparation of 7-[2-(aminothiazol-4-yl)-2-(trityloxyimino)-acetamido]-3-vinyl-3-cephem-4-carboxylic acid dicyclohexylamine salt

N,O-bistrimethylsilylacetamide (8.0 ml) is added in 15 min to a suspension of 7-amino-3-vinyl-3-cephem-4-carboxylic acid (7.5 g) in N,N-dimethylacetamide (50 ml) at 25°C. After further 20 min, 2-(aminothiazol-4-yl)-2-(trityloxyimino)acetic acid S-mercaptobenzothiazolic ester (19.8 g) is added and the mixture is stirred at this temperature until complete conversion of 7-amino-3-vinyl-3-cephem-4-carboxylic acid (HPLC analysis). After completion of the reaction, ethyl acetate (250 ml) and methanol (3 ml) are added and the mixture is stirred for 15 minutes. Water is then added (200 ml) and stirring is continued for further 15 min.

The phases are separated and the organic one is washed with a 20% sodium chloride solution in water (200 ml). The phases are separated and dicyclohexylamine (7.2 ml) is added to the organic phase in 15 min. Formation of crystals is observed. The mixture is allowed to stand for further 15 min, cooled to 0°C and stirred at this temperature for 1 hour. The precipitate is filtered, washed with ethyl acetate (100 ml) and dried. 25.8 g of the title compound are obtained.

Example 4

Preparation of 7-[2-(aminothiazol-4-yl)-2-(trityloxyimino)-acetamido]-3-vinyl-3-cephem-4-carboxylic acid (R)-(+)-α-methylbenzylamine salt

The same procedure as example 3 is initially followed. After washing the organic phase with aqueous sodium chloride, (R)-(+)-α-methylbenzylamine (4.6 ml) is added in 15 minutes. Formation of crystals is observed. The mixture is allowed to stand for further 15 min, cooled to 0°C and stirred at this temperature for 1 hour. The precipitate is filtered, washed with ethyl acetate (100 ml) and dried. 20.4 g of the title compound are obtained.

^{1}H-NMR (DMSO-d_6, 300 MHz): 9.84 (1H, d, J=8.0 Hz, -CONH-), 7.49-7.18 (20H, m, 4x*Ph*), 7.01 (1H, dd, J=17.6 and 11.0 Hz, -CH=CH_2), 6.59 (1H, s, H-heteroaryl), 5.77 (1H, dd, J=8.0 and 5.0 Hz, -CONH-CH-), 5.20 (1H, d, J=17.6 Hz, -CH=CHH trans), 5.13 (1H, d, J=5.0 Hz, -CON-CH-), 4.97 (1H, d, J=11.6 Hz, -CH=CHH cis), 4.34 (1H, q, J=6.9 Hz, CHMe benzylamine), 3.58 (1H, AB system, J_{AB}=17.1 Hz, -SCH_2), 3.45 (1H, AB system, J_{AB}=17.1 Hz, -SCH_2), 1.47 (3H, d, J=6.9 Hz, Me).